III. "On the Improvement of the Spectroscope." By Thomas Grubb, F.R.S. Received April 30, 1874.

The importance, as an instrument of research, which the spectroscope has reached within a few years, renders any improvement therein a matter of general scientific interest. Hitherto it has been under a disadvantage, which, though slight in amount in those cases in which the dispersive power of the instrument is moderate, becomes a rather serious annoyance to the observer when a number of prisms are used in serial combination, and the curvature of the spectral lines is proportionally increased, and only to be restrained *in appearance* by using a narrow breadth of the spectrum.

I have lately thought of a very simple and practical remedy (which may indeed have occurred to others, but which I have not seen mentioned), whereby those lines are rendered palpably straight in a very large field; but previous to describing it, it is desirable to refer to a statement appearing in the 'Astronomical Notices' for last month (March), viz. that the spectral lines can be rendered perfectly straight simply by returning them (after their first passage through a series of prisms arranged for minimum deviation) by a direct reflection from a plane mirror; and, further, that this has been accomplished in a spectroscope in construction for the Royal Observatory.

Such a statement has, as might be expected, produced several inquiries; in one case the querist is much interested, viz. by having a very large spectroscope in hand which, from its construction, involves the question of straight or curved lines resulting. It therefore seems desirable to remove any illusion which may be entertained, by a short consideration of the economy of the spectroscope, so far as the question of curvature is concerned.

The curvature of the spectral lines may be considered a function of the dispersion of a prism; it (the curvature) not only always accompanies the dispersion, but, further, its character is always the same with respect to the dispersion—that is to say, the centre of curvature will be found invariably to lie in the same direction with respect to the direction of the dispersion, the lines being invariably concave towards that end of the spectrum having the more refrangible rays*. This (which admits of the clearest proof) is adequate to show the impossibility that, by any

* Professor Stokes has indeed investigated a form of compound prism in which the resulting lines are straight, and on the same principle we may combine prisms (using of course media of different optical powers) in which, with *a balance* of dispersion remaining, the curvature might be found reversed; but this does not affect the general law. The curvature in that compound prism (which was the result of various trials, and first used in the spectroscope of the Great Melbourne Telescope, and now, I apprehend, in pretty general estimation and use) probably has a less proportional curvature of the lines than the simple prism.

kind of inversion, whether by reflections or otherwise, we can neutralize the curvature while doubling the dispersion.

If we examine the spectrum, as produced by a series of prisms placed in the position of minimum deviation, we necessarily find that the lines of higher refrangibility, also their centres of curvature, lie towards the centre of the polygon which the prisms themselves affect; and if we arrest the rays at any part of the circuit, and reflect them directly back by a plane mirror, this reflection reverses (right for left) not only the direction of the centre of curvature of the lines, but also the direction of the spectrum itself, both which are consequently doubled in amount after the rays have performed the second, or return, passage through the prisms; or (conversely) if, after the first passage through the prisms, we reflect the rays so as to pass through a similar set in such manner as to neutralize the curvature of the first set, we shall find the resulting dispersion reduced to zero.

The writer of the article having alluded to a difference between the reflection as given by a plane mirror and a prism of (double) total reflection, it may be observed that, so far as the dispersion and curvature are concerned, the cases are practically identical, the difference being that, in the double reflection, there is a *vertical* inversion of the spectrum, which, however, produces no discernible effect in either the spectrum or curvature of the lines; and as the spectroscope constructed with the double reflecting prism is known to produce, with double dispersion, double curvature, we here have an additional proof, if such were required, that the single reflecting mirror does the same.

The remedy, or means of producing straight spectral lines, which I have alluded to, is simply that of constructing the "slit" with curved instead of rectilinear edges. There is but little practical difficulty incurred in construction, and no apparent objection to its use. It may be objected that for each variation of prism-power in use there should be a special slit. It is, however, only in spectroscopes arranged for high dispersion that the curvature becomes objectionable; in such there is seldom a change required, and a single slit of medium balancing-power would probably remove all practical difficulty, or objectionable curvature of the lines. I have found by trial that, when two compound prisms were in use, giving a dispersion from A to H of nearly 14°, the spectral lines were straight in a field of one degree, when the radius of curvature of the slit was made 1·25 inch.

[*Note on the above Paper.*

If a ray of light be refracted in any manner through any number of prisms arranged as in a spectroscope, undergoing, it may be, any number of intermediate reflections at surfaces parallel to the common direction of the edges of the prisms—or, more generally, if a ray be thus refracted

or reflected at the surfaces of any number of media bounded by cylindrical surfaces in the most general sense (including, of course, plane as a particular case), the generating lines of which are parallel, and for brevity's sake will be supposed vertical, and if α be the altitude of the ray in air, α', α'', ..., its altitudes in the media of which the refractive indices are μ', μ'', ..., then

(1) The successive altitudes will be determined by the equations

$$\sin \alpha = \mu', \sin \alpha' = \mu'', \sin \alpha'' = \ldots\ldots,$$

just as if the ray passed through a set of parallel plates.

(2) The course of the horizontal projection of the ray will be the same as would be that of an actual ray passing through a set of media of refractive indices $\frac{\mu' \cos \alpha'}{\cos \alpha}$, $\frac{\mu'' \cos \alpha''}{\cos \alpha}$, ... instead of μ', μ'', ... As $\alpha' < \alpha$, the fictitious index is greater than the actual, and therefore the deviation of the projection is increased by obliquity.

These two propositions, belonging to common optics, place the justice of Mr. Grubb's conclusions in a clear light.—April 30, G. G. Stokes.]

May 7, 1874.

WILLIAM SPOTTISWOODE, M.A., Treasurer and Vice-President, in the Chair.

In pursuance of the Statutes, the names of the Candidates recommended for election into the Society were read from the Chair as follows :—

Isaac Lowthian Bell, F.C.S.	John Eliot Howard, F.L.S.
W. T. Blanford, F.G.S.	Sir Henry Sumner Maine, LL.D.
Henry Bowman Brady, F.L.S.	Edmund James Mills, D.Sc.
Thomas Lauder Brunton, M.D., Sc.D.	Rev. Stephen Joseph Perry, F.R.A.S.
Prof. W. Kingdon Clifford, M.A.	Henry Wyldbore Rumsey, M.D.
Augustus Wollaston Franks, M.A.	Alfred R. C. Selwyn, F.G.S.
Prof. Olaus Henrici, Ph.D.	Charles William Wilson, Major R.E.
Prescott G. Hewett, F.R.C.S.	

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read :—